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## **The advantage of completely laparoscopic gastrectomy with linear stapled reconstruction: A long-term follow-up study**

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## Abstract

**Background:** Completely laparoscopic gastrectomy with intracorporeal anastomosis was introduced to achieve safer anastomosis and smaller scars. Although several reports have shown the feasibility of linear-stapled anastomosis, there are no studies of a large number of patients assessing the long-term complications and functional outcomes.

**Methods:** This retrospective study included 345 patients that had intended to undergo completely laparoscopic distal or total gastrectomy with linear-stapled anastomosis between September 2005 and January 2012. This study evaluated both the short- and long-term complications, as well as the endoscopic findings, changes in body weight and serum albumin.

**Results:** Completely laparoscopic gastrectomy was successfully achieved in 342 patients (99.1%). Short-term complications occurred in 59 patients (17.3%). Reconstruction-related complications were observed in 19 patients (5.6%). Three patients with anastomotic leakage required reoperation. No patient experienced anastomotic stenosis over a mean follow-up period of 29.6 months. Two patients underwent an emergency operation for an internal hernia after total gastrectomy. Adhesive intestinal obstruction was observed in 5 patients (1.5%), but all were resolved without surgical intervention. Body weight loss at two years after distal and total gastrectomy was 7.2% and 13.9%, which were similar to previous reports of open surgery.

**Conclusion:** Completely laparoscopic gastrectomy with linear-stapled anastomosis is a feasible choice for gastric cancer patients with some potential long-term advantages such as less anastomotic stenosis and fewer adhesive intestinal obstructions.

## Introduction

Laparoscopic surgery was introduced into gastric cancer in early 1990's. The number of patients undergoing laparoscopic gastrectomy is rapidly increasing, especially in eastern Asia, where gastric cancer is frequently diagnosed in early stage. The initial laproscopic operations were "laparoscopy-assisted" distal gastrectomy, in which reconstruction was performed through a minilaparotomy after gastrectomy had been completed laparoscopically<sup>1</sup>. An extracorporeal reconstruction through a minilaparotomy has the advantage that surgeons can perform anastomosis in a similar fashion to that employed in open surgery. However, extension of the laparotomy is often necessary to obtain a better view for secure anastomosis in obese patients. Longer laparotomy could compromise one of the benefits of laparoscopic surgery, minimal abdominal wall injury. Furthermore, the procedure is more difficult in cases requiring transection at a more proximal site, because of the limited work space even under larger laparotomy.

Intracorporeal anastomosis has been introduced by several surgeons to solve these problems. The first successful intracorporeal Billroth-II reconstruction using linear staplers was reported in 1992 by Goh et al.<sup>2</sup>. Completely laparoscopic distal gastrectomy with intracorporeal Billroth-I anastomosis using linear staplers was reported by Kanaya et al in 2002.<sup>3</sup>. Completely laparoscopic distal gastrectomy has gradually increased<sup>4, 5</sup>. Most intracorporeal reconstruction employs linear staplers for anastomoses, although circular staplers have been used in open gastric surgery for many years. Linear staplers may be preferred for laparoscopic surgery because of their easier application through trocars and easier insertion into the duodenum or jejunum. There are reports of successful application of linear staplers for intracorporeal esophagojejunostomy, which enables completely laparoscopic total gastrectomy<sup>6, 7</sup>.

The potential advantages of completely laparoscopic gastrectomy include safer anastomosis under better visualization and less postoperative adhesion, as well as a smaller scar. The method of reconstruction and anastomotic procedure following gastrectomy could affect the incidence of long-term postoperative complications, such as anastomotic stenosis, adhesive small bowel obstruction, and internal hernia. Although several intracorporeal anastomotic techniques have been reported, there are no studies of large number of patients assessing the long-term outcome as well as the technical feasibility. In this study, we examined both the short- and long-term complications as well as the nutritional status in patients who underwent completely laparoscopic distal or total gastrectomy with linear-stapled anastomosis to evaluate functional outcomes of laparoscopic linear-stapled anastomosis and advantages of completely laparoscopic gastrectomy.

## Patients and Methods

### Patient evaluation

Completely laparoscopic gastrectomy was introduced at Kyoto University Hospital in September 2005. A total of 516 patients that underwent surgery for gastric cancer between September 2005 and January 2012 were identified in the prospectively maintained gastric cancer database. In the earlier period, indication of laparoscopic surgery was up to T2 without lymph node involvement. Since July 2009, when we initiated a prospective study of laparoscopic gastrectomy for T3 or node-positive patients (UMIN000002085), patients with more advanced cancer also underwent laparoscopic surgery, when an informed consent was obtained. Among them, three hundred forty-five patients that had intended to undergo completely laparoscopic distal or total gastrectomy were included in the present study (**Figure 1**). The study protocol was approved by the ethics committee of Kyoto University. Adenocarcinoma of the stomach was histologically proven for all patients. All patients underwent multi-detector-row computed tomography (MDCT) scans of the neck, chest, and abdomen and upper endoscopy to determine the clinical stage. Patients with large tumors or bulky lymph node (LN) metastasis underwent staging laparoscopy to evaluate peritoneal dissemination. The age, sex, body weight, body mass index, and clinical stage based on the 14<sup>th</sup> version of the staging system of Japanese Gastric Cancer Association were retrieved from the prospective database<sup>8</sup>.

### Surgical technique

The patient was placed in a modified lithotomy position. The laparoscope was inserted via the umbilical port and completely laparoscopic distal or total gastrectomy with D1+ (perigastric LNs plus #7, 8a, 9) or D2 LN dissection was performed using four operating ports, as previously described. Detailed procedures for distal gastrectomy or total gastrectomy are reported elsewhere<sup>9-11</sup>. Peritoneal lavage cytology was obtained in patients with advanced gastric cancer. The location of the tumor was marked with black ink under an endoscope prior to distal gastrectomy to obtain a safe proximal margin. The excised specimen was removed through the umbilical port wound. A Billroth-I reconstruction was the preferred method following distal gastrectomy. A functional end-to-end (FETE) anastomosis, which was originally reported by Kanaya et al. was used for a Billroth-I reconstruction (**Figure 2a**)<sup>3</sup>. A Roux-en-Y reconstruction was performed in cases with duodenal invasion, a smaller residual stomach, or symptomatic gastroesophageal reflux disease. A jejunal loop was transected about 20 cm distal to the ligament of Treitz, and then side-to-side

jujunojejunostomy was performed using an endoscopic linear stapler to create a 30-cm Roux limb. The Roux limb was then brought up via the ante-colic route to create a gastrojejunostomy by a FETE anastomosis using a 45mm endoscopic linear stapler (**Figure 2b**). A Roux-en-Y reconstruction with a FETE esophagojejunal anastomosis was performed in a similar manner following a total gastrectomy<sup>6</sup>. The length of the Roux limb was 50 cm and the ante-colic route was usually used (**Figure 2c**). The detailed technique of a FETE esophagojejunal anastomosis is shown in **Figure 3 and supplemental Video 1**. The Petersen's defect was closed with running sutures using 3-0 non-absorbable thread except for earlier cases in this patient series.

#### Surgical outcome and postoperative complications

Operative time, blood loss, type of operation, extent of lymph node dissection, number of harvested lymph nodes, pathological stage, residual tumor, intraoperative, and postoperative complications were retrieved from the prospective database. Postoperative complications included all major and minor complications and were graded according to the Clavien-Dindo classification<sup>12</sup>. Short-term reconstruction-related complications included anastomotic leakage, anastomotic bleeding, anastomotic stenosis, delayed gastric emptying, intestinal obstruction, and ileus, which occurred within 30 days after operation or during prolonged hospital stay. Delayed gastric emptying was defined as an emptying disturbance requiring starvation for more than three days, when an anastomotic stenosis or mechanical bowel obstruction were excluded.

#### Patient follow-up

All patients received outpatient follow-up at least once per six months. Patients with pathological stage II or higher stage received adjuvant chemotherapy with oral S-1 for one year. Body weight, body mass index, serum albumin and other clinical data were obtained at 1, 6, 12, and 24 months after the operation. Any complications and medical conditions requiring hospitalization were recorded. Patients with distal gastrectomy had endoscopic examination once a year. Gastritis and food residue with grade 2 or higher according to the RGB (Residue, Gastritis, Bile) classification were recorded during endoscopic examination<sup>13</sup>. Reflux esophagitis was classified using the modified Los Angeles classification<sup>14</sup>. Anastomotic stenosis was also evaluated. Patients with total gastrectomy did not have routine endoscopic follow-up, but had an endoscopy when they had any symptoms or on their request.

#### Statistical analysis

Categorical data were compared with the Chi-square test or Fisher's exact test, and a  $P$ -value  $< 0.05$  was considered to be statistically significant. Continuous variables were compared using Student's  $t$ -test. A  $P$ -value  $< 0.05$  was considered to be statistically significant.

## Results

### Patient characteristics

The 345 patients had a median age of 65.2 years (range, 29-91 years), including 227 males and 118 females. The average body mass index was 22.3 (range 14.0-34.6). The pre-treatment examination diagnosed 259 patients as stage IA/IB, 51 patients as stage IIA/IIB, 28 patients as stage IIIA/IIIB/IIIC, and 7 patients as stage IV. Thirty-four patients (9.9%) received one to three cycles of neoadjuvant chemotherapy with S-1 plus cisplatin prior to the surgery.

### Surgical outcome

Surgical procedure and outcome was summarized in **Table 1**. Completely laparoscopic gastrectomy was successfully accomplished in 342 of the 345 patients (99.1%). Three open conversions were required due to uncontrolled bleeding in two cases (one in distal, one in total gastrectomy) and to an anastomotic problem in esophagojejunostomy in one case. A naso-gastric tube was caught by a linear stapler when the side-to-side anastomosis was created in the latter case, and a right thoracotomy was necessary to redo the anastomosis. Another patient had a jejunal perforation with an anvil during FETE anastomosis following total gastrectomy. The anastomosis was completed laparoscopically, after the injured jejunum was sacrificed. The reconstruction method was changed from the Billroth-I to Roux-en-Y method in two cases after failures in gastroduodenostomy following distal gastrectomy. Both patients had a duodenal injury during FETE anastomosis, which was repaired by transection at the distal side of the injury using a linear stapler, and Roux-en-Y reconstruction was successfully done under laparoscopy.

Therefore, 185 patients had Billroth-I and 56 patients had Roux-en-Y reconstruction following distal gastrectomy. The mean operative time was 291 min in patients with distal gastrectomy. Operation with Billroth-I reconstruction required 283 min in average, which was significantly shorter than the 317 min required for Roux-en-Y reconstruction ( $P=0.001$ ). D2 lymphadenectomy was performed in 135 patients (56%) undergoing distal gastrectomy, and 25 patients (24%) undergoing total gastrectomy.

R0 resection was achieved in 339 patients (98.3%). Two patients with peritoneal dissemination underwent palliative operation (R2 resection). Two patients with macroscopically curative resection

had positive peritoneal lavage cytology (R1 resection); one of those also had microscopic residual tumor on the proximal margin. The pathological evaluation revealed a positive surgical margin in two other patients. Infiltrated cancer cells were identified in the subserosal space at both margins in one patient with an extensive scirrhous tumor that underwent total gastrectomy. Another patient with type 3 tumor who underwent distal gastrectomy had scattered cancer cells identified in the submucosal space at very close site from the proximal margin.

### Short-term complications

Both reconstruction-related and –unrelated complications were evaluated in the 342 patients with successful completely laparoscopic gastrectomy (**Figure 1**). Short-term postoperative complications were observed in 59 patients (17.3%); 35 patients were after distal gastrectomy (14.6%), and 24 patients were after total gastrectomy (23.5%, **Table 1**). Nine complications were resolved without specific pharmacological treatment, and thus classified as grade I, according to the Clavien-Dindo classification. There were 11 grade III complications, including five patients that required radiological intervention (grade IIIA), and six patients underwent reoperation (grade IIIB). One patient developed an aorto-enteric fistula at the esophagojejunostomy site following esophagojejunostomy with the overlap method, and died of sudden massive hematemesis on the 31<sup>st</sup> postoperative day. Another 89-year-old patient died with sudden cardiopulmonary arrest on the third postoperative day. Mortality in this patient series was 0.6% (**Table 2**).

Reconstruction-related complications were observed in 19 patients (5.6%, **Table 3**). The most frequent reconstruction-related complication was anastomotic leakage, and was observed in 10 patients (2.9%). The frequency of leakage at the Billroth-I anastomosis, gastrojejunostomy, esophagojejunostomy and jejunal stump was 2.7%, 1.8%, 2.0%, and 1.3%, respectively. Four leakages were secondary to intraabdominal abscess, or pancreatic fistula. All secondary leakages were managed without surgical intervention. One leakage at the Billroth-I anastomosis, one leakage at the gastrojejunostomy, and one leakage at the duodenal stump following distal gastrectomy required reoperation. Delayed gastric emptying following distal gastrectomy was infrequent, but observed both in Billroth-I and Roux-en-Y reconstruction (1.6% and 3.6%, respectively). Roux stasis following total gastrectomy was observed in two patients and required fasting for 7 and 19 days, respectively. Ileus following total gastrectomy was successfully managed by decompression with a long intestinal tube. Anastomotic stenosis was not observed in any patients.

Another 53 complications in 47 patients were not related to reconstructions. Intraabdominal abscess was the most frequent, and observed in 23 patients. All patients with intraabdominal



abscess were cured with antibiotics, except for one patient who underwent surgical drainage of the abscess at the right subphrenic space. Reoperation was required for another patient with acute cholecystitis, and for two other patients with peritonitis. Peritonitis in one patient was due to a perforation of remnant stomach, which occurred on the 10<sup>th</sup> postoperative day. Thermal injury by a sealing device during the first operation was suspected. The other patient had ischemic perforation at the ileum on the fourth postoperative day, which was caused by thromboembolic occlusion of the mesenteric artery.

#### Long-term follow-up results

Twelve patients were lost to follow-up during the study period: the follow-up rate was 96.5%. A total of 31 patients died, including two surgical mortalities, 18 deaths of recurrent or progressive gastric cancer, and 11 deaths of other causes. The mean follow-up period of all 342 patients were 29.6 months (range, 2.2 to 74.6). A total of 78 patients had a history of hospitalization during outpatient follow-up (22.8%). The reasons for hospitalization are summarized in (Table 4). Patients with total gastrectomy had a higher frequency of hospitalization than those with distal gastrectomy ( $P=0.008$ ). The most common reason of hospitalization was metastasis or progression of the disease, followed by treatment of another type of malignancy, and endoscopic polypectomy of colonic polyps. Intestinal obstruction and pneumonia were the fourth most common medical conditions leading to readmission. The frequency of intestinal obstruction and pneumonia was significantly higher in patients after total gastrectomy ( $P=0.003$ ).

Two patients with intestinal obstruction after total gastrectomy with symptoms suggesting strangulation required emergent operation. Internal hernia of the upper jejunal loop through the jejunal mesenteric defect of the Y anastomosis was identified in both patients. Reposition of the jejunal loop rescued the circulation and saved it without resection in one patient. However, resection of the affected ischemic loop and a new Roux-en-Y reconstruction was necessary in the other patient. One patient required decompression with a long intestinal tube. The symptoms of the other four patients were resolved spontaneously by fasting without decompression.

Four other patients underwent abdominal surgery during the follow-up period. One patient with acute right subcostal pain had an emergency operation for suspected perforation peritonitis. No responsible lesion was identified on laparoscopic examination, and the patient was fully recovered with antibiotics. The others were incisional hernia repair for the umbilical wound, open cholecystectomy and bile duct exploration for acute cholangitis, and appendectomy.

Two patients underwent endoscopic treatment. One patient had endoscopic submucosal

dissection for a metachronous early gastric cancer. Another patient on daily aspirin had endoscopic hemostasis with clipping for telangiectasia in the remnant stomach. No patient developed anastomotic stricture that required endoscopic dilatation.

#### Endoscopic findings

A total of 154 patients that underwent distal gastrectomy (117 with Billroth-I and 37 with Roux-en-Y reconstruction) had an endoscopic examination at one year following surgery (**Table 5**). Remnant gastritis were the most frequent findings and observed more often in patients with Billroth-I reconstruction, than in those with Roux-en-Y reconstruction (50.4% vs. 21.6%,  $P=0.002$ ). Reflux esophagitis was found in 46 patients with similar frequency following Billroth-I and Roux-en-Y reconstruction. Most of those were classified as grade M, according to the modified Los Angeles classification of reflux esophagitis. There were only four patients with grade A, and one patient with grade B esophagitis. No grade C or higher esophagitis was found. More than a moderate amount of food residue in the remnant stomach was observed in 21 patients. The ratio of patients with food residue was similar in Billroth-I and in Roux-en-Y reconstruction.

Twenty-six patients underwent endoscopic examination at one year following total gastrectomy. Reflux esophagitis was found in three patients (11.5%); all three cases were classified as grade A. No anastomotic stenosis was found in any of the patients with endoscopic evaluation, irrespective of the reconstruction methods.

#### Changes of body weight and serum albumin

Among 186 patients who had a follow-up of longer than two years, 37 patients that received chemotherapy in an adjuvant setting or for recurrent disease, two patients with uncontrolled ascites, and one patient on hemodialysis were excluded, and the rest of 146 patients were analyzed for changes of body weight and serum albumin value. Body weight ratios were calculated in comparison to the preoperative weight at 1, 6, 12, and 24 months after surgery for each patient. Patients were separated into three groups depending on the types of surgery they underwent; distal gastrectomy with Billroth-I reconstruction (DGBI,  $n=97$ ), distal gastrectomy with Roux-en-Y reconstruction (DGRY,  $n=19$ ), and total gastrectomy (TG,  $n=30$ ). The mean % body weight of each group of patients at 1, 6, 12, and 24 months after surgery were, 93.0, 92.6, 92.8, and 92.5, respectively, in the DGBI group; 92.2, 90.9, 92.5, and 93.9, respectively, in the DGRY group, and 90.7, 86.9, 86.9, and 86.1, respectively, in the TG group (**Figure 4**). There was a significant reduction of body weight in the first month, and no significant changes of body weight thereafter in the in the DGBI and DGRY groups.

The body weight continued to decrease until 12 months in the TG group. The mean % body weight of the DGBI group was significantly higher than that of the TG group at 6, 12, and 24 months after gastrectomy ( $P=0.001$ ,  $<0.001$ ,  $<0.001$ , respectively). The mean % body weight of the DGRY group was also significantly higher than that of the TG group at 12 and 24 months after gastrectomy ( $P=0.020$  and  $0.006$ , respectively). There was no difference between the DGBI and DGRY group at any time point.

Baseline values of serum albumin were similar in patients before distal and total gastrectomy ( $4.13 \pm 0.33$  and  $4.05 \pm 0.35$ , respectively). However, the values in patients at one year after distal gastrectomy were significantly higher than those in patients after total gastrectomy ( $4.15 \pm 0.26$  vs.  $3.99 \pm 0.39$ ,  $P=0.044$ ). The difference was still significant after two years ( $4.17 \pm 0.27$  vs.  $3.99 \pm 0.31$ ,  $P=0.003$ ).

## Discussion

This study found that completely laparoscopic gastrectomy with intracorporeal anastomosis was successfully accomplished in 99.1% of patients, indicating the technical feasibility of the methods using linear staplers. Although the average BMI in this series is lower than a common Western BMI, our methods would be also suitable for Western patients, because intracorporeal reconstruction is rather easier than reconstruction through mini-laparotomy in obese patients. There were a few troubles during linear-stapled anastomosis, but most of troubles could be managed laparoscopically; only one conversion was due to anastomotic trouble in this study. Reconstruction can be done without hand suturing by using the FETE anastomotic technique in most cases. However, laparoscopic suturing skill is still important, to repair any injuries, or to close the entry hole in difficult cases.

The incidence of reconstruction-related complications over 30 days after surgery was 5.5%, which is lower than the ratio reported in open surgery, considering the fact that this study also includes total gastrectomy<sup>15, 16</sup>. Anastomotic leakage was the most frequent reconstruction-related complication and occurred in 2.9%, which is comparable to the ratio in open surgery. However, more than half of the leaks were minor secondary leakage following intraabdominal abscess, and required no intervention. Delayed gastric emptying is another problem following distal gastrectomy, which occurred in 1.6% and 3.6% of patients following Billroth-I and Roux-en-Y reconstruction in this study. The ratio of delayed gastric emptying following Roux-en-Y reconstruction is slightly higher in comparison to the ratio reported in a larger series in open surgery (1.9%)<sup>17</sup>. However, that study only included patients who stayed at the hospital for more than 28 days, while the current study included

all patients who required re-fasting for more than three days. Adapting their definition to the current study would lower the ratio to 1.8%, similar to the previous study. It should be noted that no patient experienced anastomotic stenosis or bleeding within 30 days after surgery. This could be one of the advantages of the linear-stapled method, because the size of the stoma is theoretically larger than one after using a circular stapler, and hemostasis can be confirmed from the luminal side through the entry hole during the operation.

The main outcome of this study was to evaluate long-term as well as short-term outcomes of intracorporeal linear-stapled anastomosis following gastrectomy. Anastomotic stenosis occurs in 6 to 17% of patients within a few months after circular-stapled anastomosis, or even later<sup>18-21</sup>. FETE anastomosis could reduce anastomotic stenosis, because a stoma larger than 30 mm diameter can be created, when 45 mm-staplers are used. However, there is no data on a longer follow-up of patients that underwent laparoscopic gastrectomy with intracorporeal linear-stapled anastomosis. This study identified no patient with anastomotic stenosis among 342 patients over a mean follow-up of 2.5 years. This finding clearly showed the superiority of the linear-stapled method over circular stapling with regard to reducing anastomotic stricture. The reduced risk of anastomotic stenosis could contribute to better quality of life for patients, because the symptoms of stenosis is one of the most important factors impairing the quality of life in patients after gastrectomy.

Adhesive intestinal obstruction is another complication that could occur at later period after open gastric surgery. Readmission was necessary to treat adhesive small bowel obstruction in five patients in the current series (1.5%). The frequency is much lower in comparison to previous reports of open gastrectomy (6.5% in two years and 12% in three years)<sup>22, 23</sup>. Moreover, most of patients resolved spontaneously without decompression. No patient with adhesive intestinal obstruction required operation in this study. These findings suggest that laparoscopic gastrectomy without mini-laparotomy reduces intraabdominal adhesions and lowers the frequency of postoperative small bowel obstructions. On the other hand, the reduced adhesion might increase the risk of internal hernia. Internal hernia through Petersen's defect or a jejunal mesenteric defect is one of the dangerous complications of laparoscopic bariatric surgery with Roux-en-Y reconstruction<sup>24, 25</sup>. Two patients needed emergency surgery for internal hernia in the current series, both of which occurred through a mesenteric defect. Those defects were not closed during the earlier period in this study. A higher percentage of internal hernia was reported in a large bariatric surgery patient series, and closure of possible spaces is recommended to reduce the frequency<sup>24, 25</sup>. Internal hernia is a rare complication following gastrectomy, but it could lead to massive strangulation and risk the life of patients once happens. Therefore, closure of defects is recommended when gastrectomy with

Roux-en-Y reconstruction is performed. Pneumonia was the fourth most common cause of readmission. Intriguingly, patients after total gastrectomy had a higher frequency of pneumonia than patients after distal gastrectomy ( $P=0.003$ ). The higher tendency to develop pneumonia in patients after total gastrectomy may be related to esophageal reflux, because three of six cases were diagnosed as aspiration pneumonia.

Body weight loss at two years was similar between Billroth-I and Roux-en-Y reconstruction following distal gastrectomy in this study (7.5% and 6.1% at two years). These body weight changes seems to be smaller than those reported in open gastrectomy, where a decrease of around 10% was reported both after Billroth-I and Roux-en-Y reconstruction<sup>26</sup>. Short- and long-term outcomes including reconstruction-related complications were also similar between Billroth-I and Roux-en-Y reconstruction. There was no much difference in the endoscopic findings at one year after surgery, except for a higher frequency of remnant gastritis in patients following Billroth-I reconstruction. Although Roux-en-Y reconstruction may be better in terms of reducing gastritis, it also has some disadvantages such as the difficulty of endoscopic biliary intervention. One patient needed a surgery for biliary stones at four years after distal gastrectomy with Roux-en-Y reconstruction in the current series, because endoscopic intervention was impossible. Moreover, endoscopic gastritis following Billroth-I reconstruction is symptom-free in most cases. Therefore, no definite advantage of either type of reconstructions was demonstrated in this study. This clinical practice prefers Billroth-I reconstruction because of shorter operation time. The current study showed that body weight loss after total gastrectomy is larger than that after distal gastrectomy. Serum albumin value after total gastrectomy was also slightly lower than that after distal gastrectomy. However, the mean body weight loss after total gastrectomy in this study (13.9%) is similar or better in comparison to previous reports of open total gastrectomy<sup>27, 28</sup>. This suggests that laparoscopic total gastrectomy could offer at least equivalent postoperative outcomes as open surgery from the nutritional point of view.

In summary, the current study showed that completely laparoscopic gastrectomy with linear-stapled anastomosis is a feasible choice for gastric cancer patients, with less postoperative reconstruction-related complications. Although this is a retrospective study at a single institute, longer observation of patients revealed additional potential advantages, such as less anastomotic stenosis, less adhesive intestinal obstruction, and better nutritional outcome. A prospective randomized study comparing long-term oncological and nutritional outcomes is necessary to confirm these results.

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## Figure legends

### Figure 1

Flow diagram for selecting patients for the study. Median follow-up period of the cohort for evaluation of complications was 29.6 months. LDG: laparoscopic distal gastrectomy, LTG: laparoscopic total gastrectomy.

### Figure 2

Schematic illustration of various types of reconstruction using linear staplers following gastrectomy. a. Billroth-I reconstruction (so called 'Delta-shaped anastomosis'). b. Roux-en-Y reconstruction following distal gastrectomy. c. Roux-en-Y reconstruction following total gastrectomy.

### Figure 3

Linear-stapled esophagojejunal anastomosis. a. A naso-gastric tube is introduced through a small hole made on the left edge of the esophageal stump. b. The esophagus (E) and the jejunal limb (J) are anastomosed in a side-to-side fashion. A linear stapler is inserted into the esophageal lumen using the naso-gastric tube as a guide. c. The entry hole is roughly closed with staplers for tissue approximation. d. Both edges of the entry hole are lifted by the assistant. e. Closure is completed by application of a linear stapler. f. Final view of the esophagojejunostomy.

### Figure 4

Time-course changes of body weight following gastrectomy in comparison to baseline value. DGBI: distal gastrectomy with Billroth-I reconstruction, DGRY: distal gastrectomy with Roux-en-Y reconstruction, TG: total gastrectomy. \* Value of DGBI is significantly higher in comparison to total gastrectomy ( $P<0.01$ ). † Value of DGRY is significantly higher in comparison to total gastrectomy ( $P<0.01$ ).

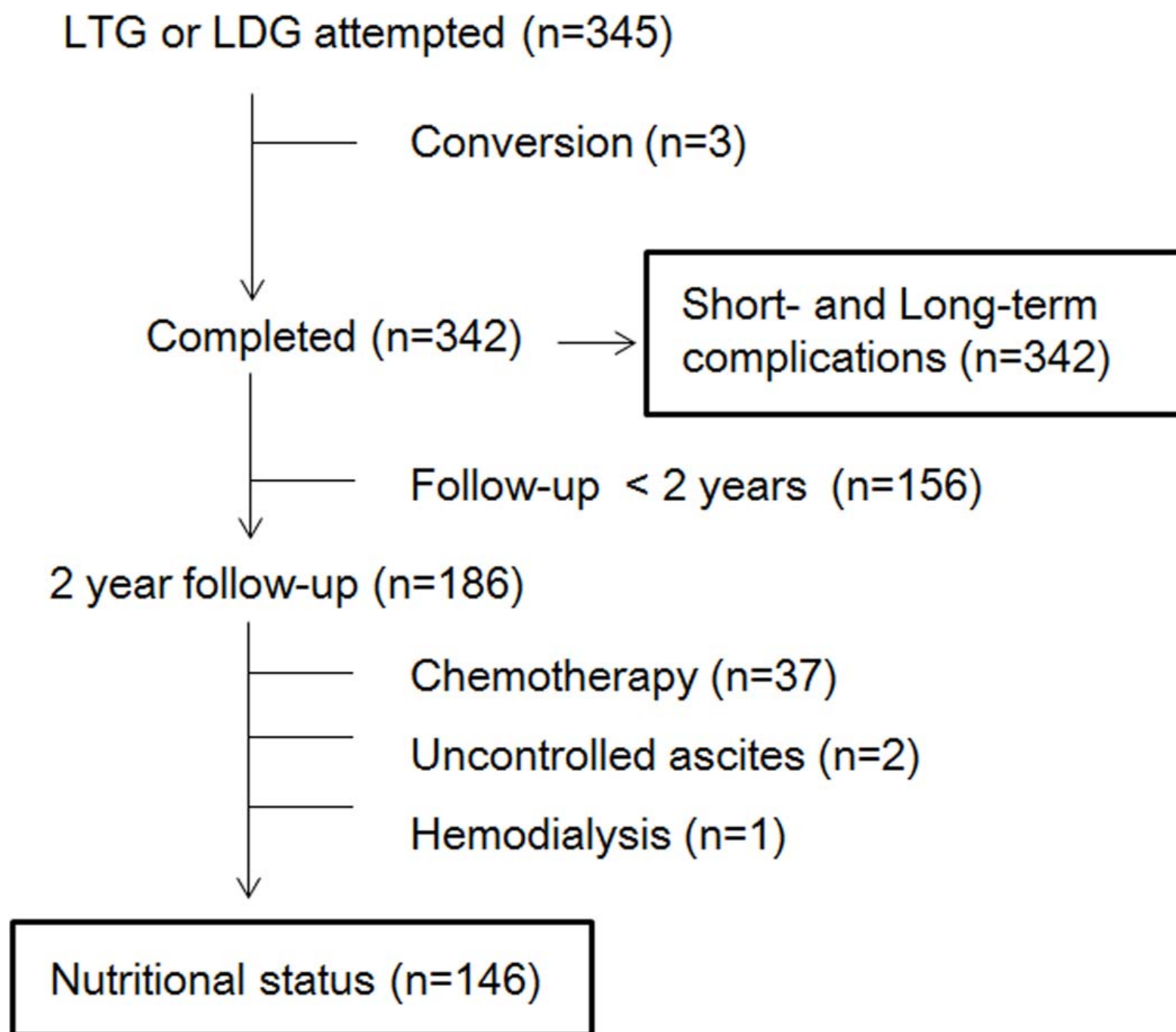


Figure 1

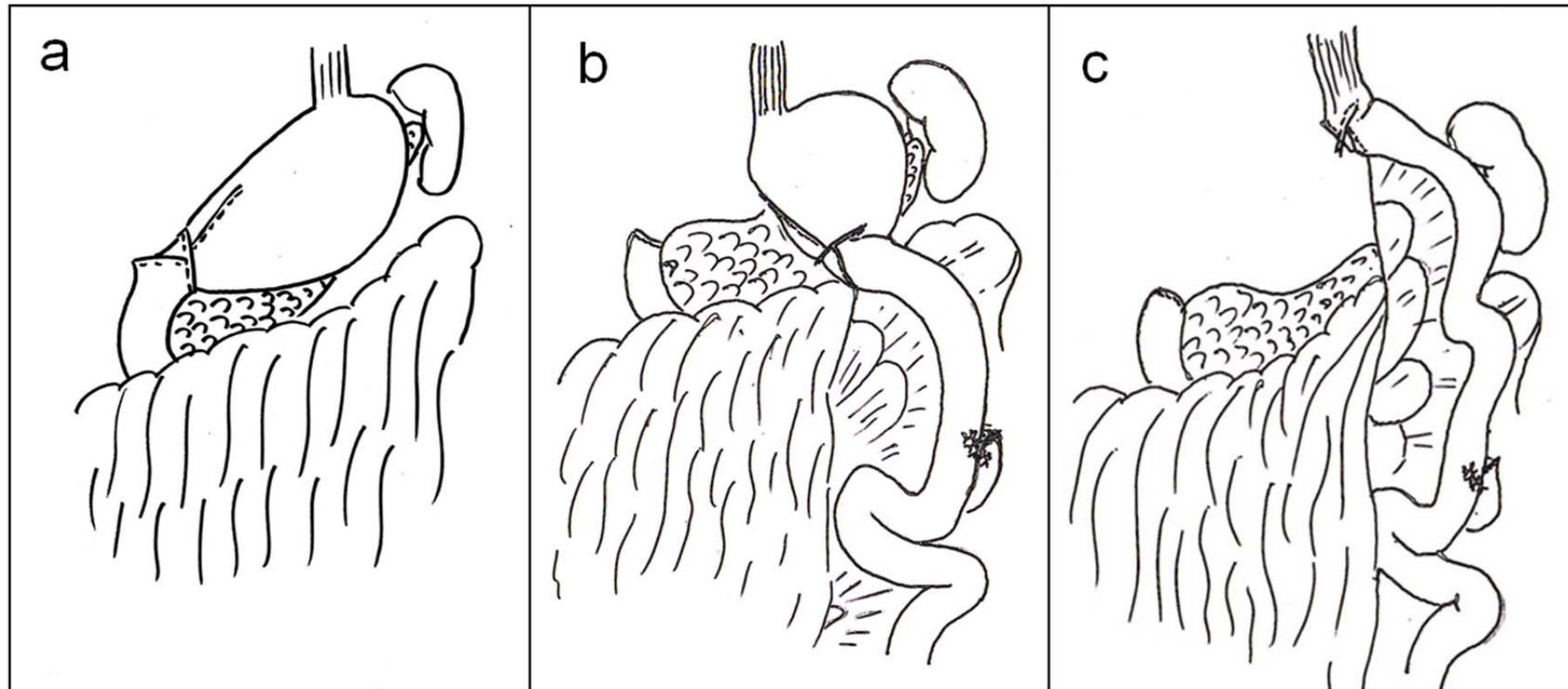


Figure 2

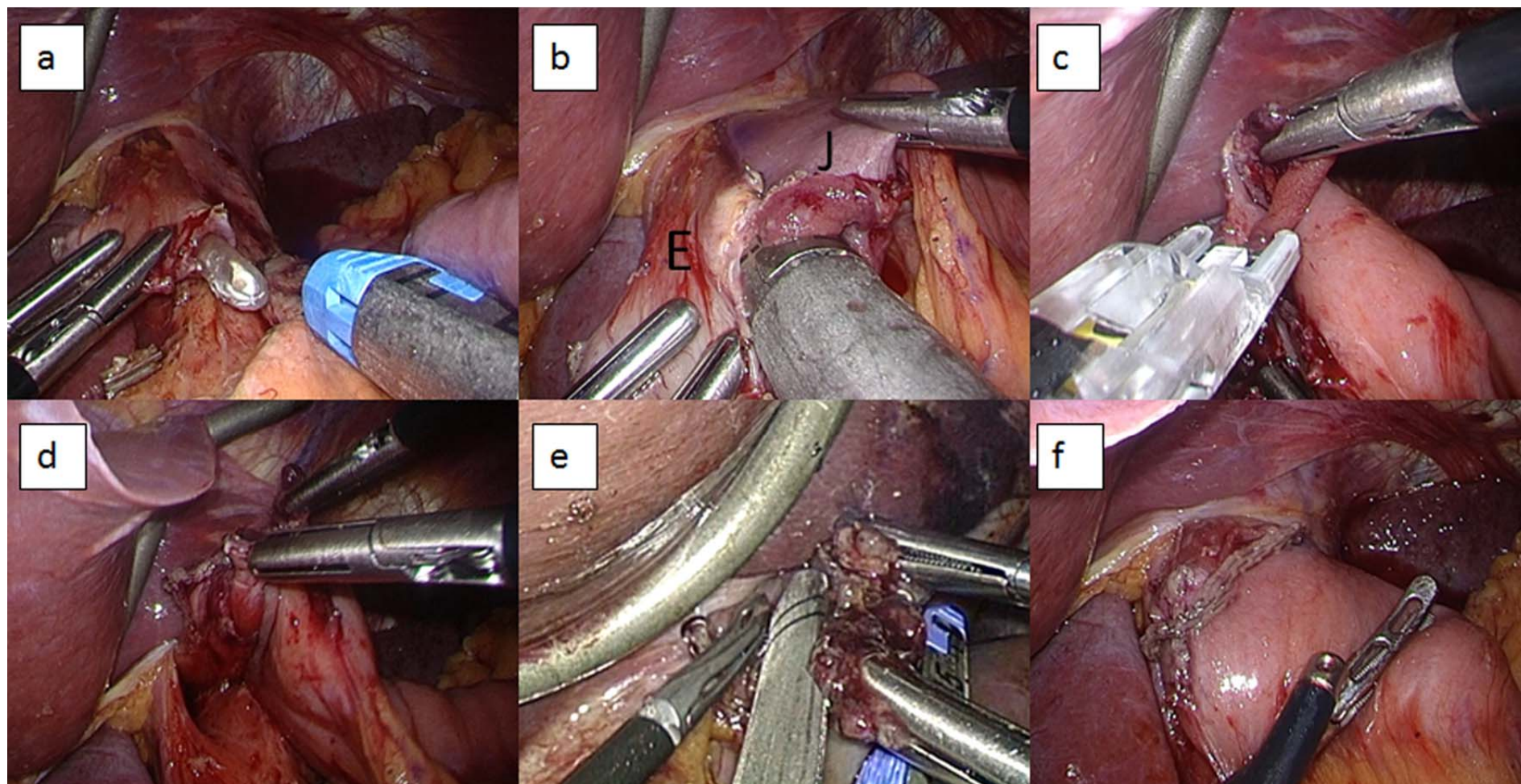


Figure 3



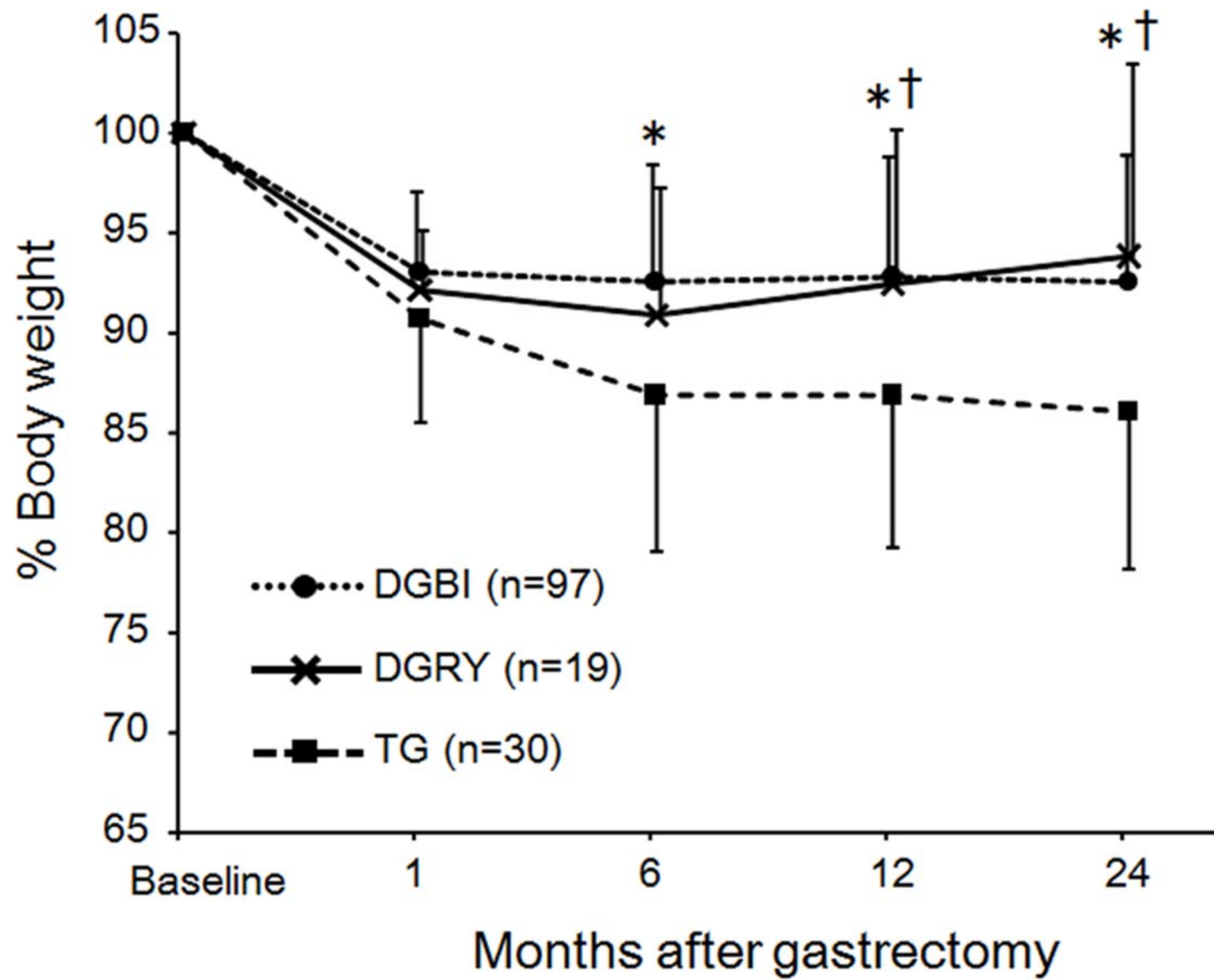


Figure 4